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Volume 3, Number 3, July 1982

Genetic Testing in the Workplace

Asbestos Identification and Sampling

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Overview of VDT Ergonomics

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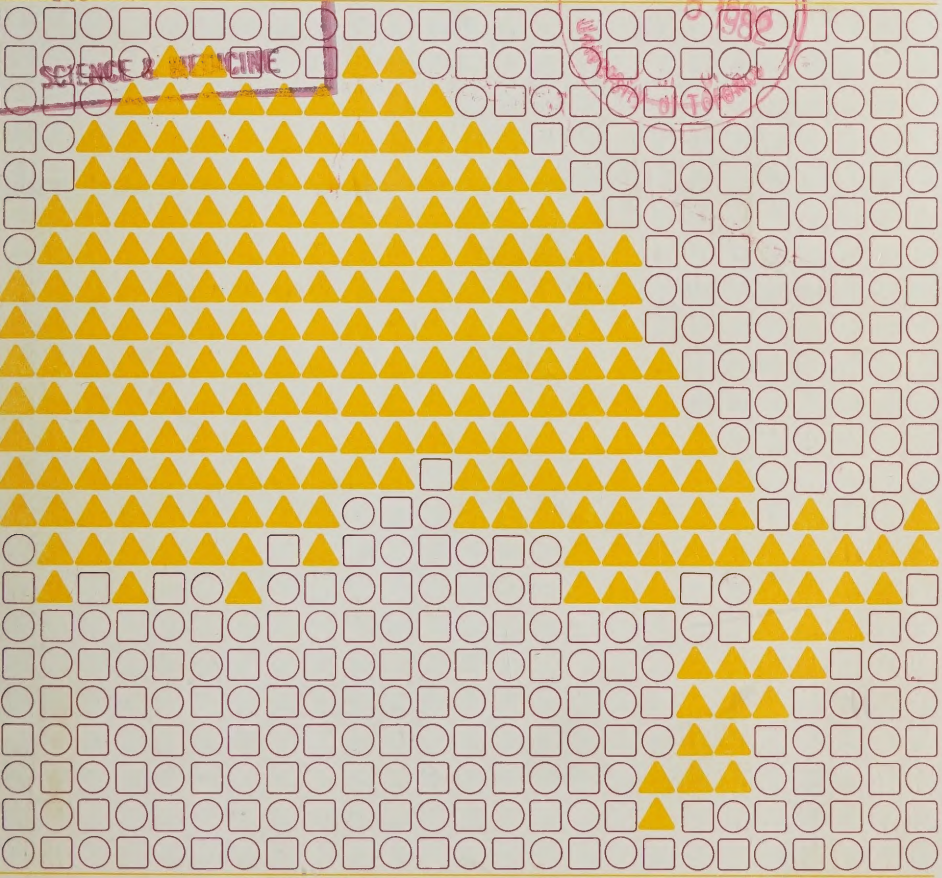

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Occupational Health in Ontario

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3. Gamble JF, and Battigelli MC. Epidemiology. In: Clayton GD and Clayton FE. eds. Patty's industrial hygiene and toxicology. New York: McGraw Hill, 1978: Vol 1; 113-116.

Rachelle S. Beauchamp,
Ph.D.

Genetic Testing in the Workplace

Summary

Methods of genetic testing, including tests for 'genetic hypersusceptibility' as well as techniques for monitoring damage to DNA and chromosomes, are reviewed and evaluated. It is concluded that there is a fundamental difference between these two categories of tests. On the one hand, there is little evidence linking any genetic condition with an increased risk of developing occupationally-related disorders. Therefore, in general, routine screening for 'genetic hypersusceptibility' is not warranted. On the other hand, the use of cytogenetic and other genetic monitoring techniques is widely accepted. However, since the clinical significance of positive results in such assays for genetic damage is not well understood, these results should be interpreted cautiously.

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New methods of medical surveillance now being developed for use in the workplace may help to create safer working conditions but could also raise difficult moral, ethical and legal questions in the area of labour relations. A particular area of concern, among labour groups and in the popular press, is 'genetic testing', or tests which involve an examination of the structure and function of the hereditary material, DNA. Mr. Anthony Mazzochi, former director of health and safety for the Oil Chemical and Atomic Workers International Union, has summarized these concerns by stating that, 'the 1980s will be an era of genetic confrontation.'[1]

At present, genetic tests are used by industry for two different purposes:

1. as part of pre-employment screening programs, to detect genetically 'hypersusceptible' individuals (i.e. those more susceptible than the majority of workers to particular workplace hazards); and
2. as a form of 'biological monitoring', to detect possible DNA damage in workers exposed to certain hazardous chemical or physical hazards. Because many of the long-term, deleterious effects of hazardous chemicals (i.e. mutagenesis and carcinogenesis) result from damage to DNA, such tests may be an important protective device.

Recently, a series of articles in *The New York Times*[1] raised doubts about the scientific, ethical and legal validity of the first (but not the second) class of tests and prompted NIOSH and OSHA to examine the issue of genetic testing by industry. This paper will:

- briefly describe and discuss the methods of genetic testing which are now available;
- detail the US response to this question;
- discuss some of the policy issues raised by such testing;
- speculate on future developments in genetic testing.

Tests for Genetically 'Hypersusceptible' Workers

Genetic factors can affect an individual's response to toxic substances. For example, such factors could influence the absorption, metabolism or excretion of a toxic material. In most cases, these 'genetic factors' are altered proteins, for example, enzymes (such as glucose 6-phosphate dehydrogenase) or structural proteins (such as haemoglobin). Often in an occupational setting only heterozygotes (individuals with one normal and one altered gene) are the real subject of concern.

Although many examples of altered protein function have been studied in humans and animals, few are known to significantly affect susceptibility to occupational exposures. The following traits are among those that have been considered by some to be relevant to industrial exposures to toxic substances:[2,3,4]

- Sickle Cell Trait,
- Glucose 6-Phosphate Dehydrogenase Deficiency,
- Serum Alpha-1 Antitrypsin Deficiency,
- Histocompatability Antigens (HLA) and Ankylosing Spondylitis, and
- Aryl Hydrocarbon Hydroxylase Inducibility.

Sickle Cell Trait

Sickle cell haemoglobin (Hb^s) is a mutant or variant type of haemoglobin in which the normal β chain, is replaced by the βs chain. As a result of a single amino acid substitution, Hb^s is less effective than normal haemoglobin in carrying oxygen. Individuals homozygous for sickle cell haemoglobin (i.e. those with $2\beta^s$ genes) have sickle cell anaemia, which has various clinical manifestations. The much larger group of heterozygous individuals (i.e. those with one β^s gene and one normal β gene) have the benign sickle cell trait. This trait can be detected by chemical tests (which are relatively cheap and easy to perform) capable of separating normal haemoglobin from haemoglobin s: Such procedures include electrophoretic testing, the dithionite (metabisulphite) test or a commercial test based on differential solubility, (Sickledex). Recently, a new technique has been developed which detects the trait by direct examination of enzyme-digested DNA.

The sickle cell trait is not very prevalent in the general Canadian population, but is fairly common among individuals whose families originated in

equatorial Africa, India or in several of the Mediterranean countries. In the United States, among individuals of African ancestry, the occurrence of sickle cell trait is estimated at about five per cent, or approximately two million individuals.

As mentioned, the sickle cell trait is generally completely benign. However, some scientists have expressed concern that individuals with this trait might be at increased risk during conditions of oxygen deprivation (e.g. at high altitudes) or when exposed to chemicals such as benzene, capable of damaging red blood cells. In the past, the US Air Force Academy rejected applicants with sickle cell trait; this policy was controversial and the academy has now decided to accept such individuals.

Glucose 6-Phosphate Dehydrogenase Deficiency

Glucose 6-phosphate dehydrogenase (G6PD) is an enzyme encoded by a gene on the X chromosome and catalyzes one step in glucose metabolism in red blood cells. G6PD deficiency exists in 100 or more enzymic variants. Under most conditions, individuals with such a deficiency (these are generally males) function normally; the most important practical consequence of G6PD deficiency is hypersusceptibility to certain drugs with oxidizing properties (e.g. primaquine and other antimalarials, phenacetin, sulphonamides, etc). Under the stress of these drugs, methaemoglobin (oxidized iron) is formed and acute haemolytic anaemia may result. The rationale for testing for G6PD deficiency in an industrial setting is that affected individuals might be particularly susceptible to haemolysis and will be at risk if exposed to such chemicals as benzene or to strong oxidizing agents.

The test for G6PD deficiency is usually based on the measurement of G6PD activity in a small sample of blood. For example,[2] one can measure spectrophotometrically the increase in optical density due to the reduction of nicotinamide-adenine dinucleotide phosphate (NADP).

The gene for G6PD deficiency is most common in individuals from central Africa and the Mediterranean countries, also in East Indians, some Orientals, Oceanians and Filipinos.[4] Again, the incidence of G6PD deficiency among Canadians has not been established, but its prevalence among US blacks has been estimated at six to 15 per cent.

Serum Alpha-1 Antitrypsin Deficiency

Serum alpha-1 antitrypsin (SAT) is a protein which inhibits the activity of the proteolytic enzyme trypsin. It has been postulated that, during inflammatory processes in the lungs, SAT protects the alveolar lining against proteolytic enzymes released by white blood cells. Many different alleles have been identified at the SAT gene locus; a number of these are associated with SAT deficiencies. Individuals homozygous for the severe deficiency (P_iZ) have an increased risk of developing chronic obstructive lung disease and emphysema. While heterozygotes (PiZM) are normally symptom-free, some scientists have speculated that these individuals are more likely than people with normal SAT levels to develop pulmonary disorders and hence should not be exposed to respiratory irritants. However, this thesis has not been established.[5] The frequency of heterozygotes in the general population is probably of the order of one per cent, but among individuals of Scandinavian origin, the frequency is closer to four per cent, and homozygotes occur about 1/1,000.

Histocompatibility Antigen (HLA) Systems

An enormous amount of work has been done on associations between these antigens and clinical disease. The strongest and most widely accepted correlation to date is that of the B27 antigen with ankylosing spondylitis: More than 90 per cent of ankylosing spondylitis patients possess the B27 antigen, as opposed to less than eight per cent of controls. On the other hand, no more than 20 per cent of those with the B27 antigen will develop the disorder, and, therefore, this antigen probably has little value as a prognostic tool. However, attempts have been made to use the association of the B27 antigen with ankylosing spondylitis in occupational medicine. For example, two studies on British asbestos workers concluded that there was an association between the B27 antigen and the development of asbestosis. However, a third study found no correlation and, overall, the results are not significant.

Aryl Hydrocarbon Hydroxylase Inducibility

The enzyme aryl hydrocarbon hydroxylase (AHH) activates a variety of exogenous hydrocarbon compounds, including insecticides and many chemical carcinogens. Enzyme activity is inducible, and it has been suggested that in man and other mammals, the capacity for induction may be controlled, at least in part, by a single autosomal gene locus; it has been estimated that, in man, the frequencies of the alleles are 0.28 and 0.72 for high and low inducers respectively. Therefore, the frequency for homozygous high inducers is 0.078 and for heterozygotes, 0.40.

The formation of epoxides (thought to be the carcinogenic or active metabolites of the polycyclic aromatic hydrocarbons) is determined partly by AHH. Therefore, scientists have speculated that high inducers, if exposed to PAH, may have a greater risk of developing cancer than low inducers.[6] In one study, this was shown to be the case for patients who smoke cigarettes and develop lung cancer. However, a similar effect has not been established for industrial exposures.

Evaluation of Current Tests for Genetic Hypersusceptibility

The general consensus among scientists in the government and academia (see below)[7] is that there is little evidence linking any of the conditions described with increased susceptibility to occupationally-related disorders. Therefore, at this time there appears to be little scientific basis for excluding anyone from employment on the basis of 'genetic hypersusceptibility'.

Biological Monitoring by Genetic Tests

Another application of 'genetic testing' involves using such techniques as cytogenetic testing[8] or body fluid analysis[9] in order to detect effects on workers exposed to toxic substances in the workplace. This type of biological monitoring can be used to identify 'susceptible' individuals, identify hazardous work conditions and judge the effectiveness of control technology. In principle, this approach does not differ from more conventional biological monitoring techniques, for example, the measurement of blood lead levels. Many of the methods used are identical to approaches taken in short-term

mutagenicity testing and have been recently reviewed by House[10] and Harding.[11]

1. **Cytogenetic Tests**. For such testing, samples of venous blood are taken in the conventional way and the lymphocytes are cultured and examined for signs of genetic damage. This is done either by scoring the number of chromosome abnormalities (numerical or structural) which are present or else by a newer technique termed 'sister chromatid exchange' (SCE). This latter technique measures reciprocal exchanges of DNA which are probably an indication of DNA damage.

In comparing the two techniques, the main problem with chromosome analysis is that it is subjective and requires highly trained personnel; SCE is less costly and less subjective, but the molecular mechanism is not understood. Both approaches have now been used in many occupational studies, so that a fairly large data base already exists. Among certain groups of workers (e.g. those working with vinyl chloride or benzene) correlations have been found between cytogenetic anomalies (i.e. positive test results) and exposure levels, and it has been suggested that cytogenetic tests could be used as a 'film badge' or dosimeter to monitor worker exposure to certain toxic agents.

In general, there are two main drawbacks to cytogenetic techniques; first, that tests on peripheral lymphocytes may give false negatives because they underestimate stem cell damage and are not informative about germ cell damage[12] and secondly, that the clinical significance of positive test results is not understood.

2. **Body Fluid Analysis**. These tests are a variation of the Ames or other short-term tests. Body fluids (usually urine) are collected and concentrated, and their mutagenicity is estimated with a target cell, such as salmonella bacteria or mammalian tissue culture cells. The evidence of genetic damage provided by such tests is less direct than that of cytogenetic analysis, but the tests may be more useful in an industrial setting because there is a large data base available, the cost is low, the procedure is noninvasive and a broad range of target cells can be used. One problem with such testing is that the urine of smokers is generally positive and, therefore, may mask the effects of workplace exposure to potential mutagens.

3. **Sperm Analysis.** In male workers, semen specimens can be obtained and abnormalities in sperm cells (either abnormal morphology or extra Y chromosomes) can be enumerated.[13] Two advantages of this approach are that it gives a direct indication of germ cell damage and that sperm morphology is easy to score. Some of the disadvantages are that there may be difficulty in obtaining specimens, there is no large data base available, the extra Y body test is controversial, female workers cannot be monitored, and the genetic effects of abnormal sperm are not known.

Evaluation of Genetic Biological Monitoring Techniques

In general, genetic biological monitoring techniques may have an important role in monitoring and protecting the health of workers. Of particular value are monitoring protocols which combine two different testing procedures such as cytogenetic and body fluid analysis.

As mentioned earlier, the biggest limitation of such tests is that at present the significance of positive test results for any particular individual is unclear. That is, scientists are unable to extrapolate from individual test results to individual risks. Therefore, at the moment such tests are useful only as a general index of exposure, not for picking out 'susceptible' individuals.

New Trends in Genetic Testing

Identifying Individuals with Genetic Susceptibility to Cancer

It has been known for some time that individuals with particular genetic abnormalities are predisposed to certain types of cancer.[14] For example, certain individuals with defective DNA repair (xeroderma pigmentosa or XP) are extremely sensitive to ultraviolet light and tend to develop skin cancer. However, until recently, such conditions were not of concern to industry because they were either extremely rare and/or they were part of a syndrome of clinical effects so severe as to prevent the affected individual from entering the work force.

Recently, however, it has been established that in some families certain very common types of cancer, such as breast cancer, may be linked to a specific gene.[15] In addition, in the case of certain genetic disorders linked to an increased cancer incidence

(e.g. ataxia telangiectasia and xeroderma pigmentosa), heterozygotes may also have an elevated cancer risk.[16] Increasingly, cytogenetic and linkage techniques will be able to identify individuals at risk for a particular cancer; in the field of occupational health, the question will be, 'How many people do we try to protect and how do we take care of the ones that we can't protect?'[17]

New Methods of Genetic Monitoring

Many new techniques for genetic monitoring of workers (and others) are now being developed. Some of the most promising include:

- direct assays of DNA repair;[18]
- measuring the alkylation of biological macromolecules (DNA, proteins); and
- quantitative cell mutation systems (cellular specific locus tests).[13]

As scientists become more sophisticated in their ability to manipulate DNA, new and more powerful methods for identifying individuals with altered genes will be developed. In principle, any variant DNA sequence (whether or not it has any clinical significance) can now be detected. Many of the tests presently used for monitoring will also be applicable to the area of pre-employment screening. With these techniques employers will, potentially at least, be able to uncover the most intimate details of a job applicant's genetic make-up and lifestyle. For example, employers could administer a urine mutagenicity assay to job applicants in order to screen out smokers, or use cytogenetic techniques to screen out workers with a high, basal frequency of cytogenetic abnormalities.

Present Uses of Genetic Testing

There is no direct information available on the extent to which Canadian (or Ontario) industry makes use of genetic testing techniques. From informal discussions it would appear that in some cases where workers are exposed to known carcinogens, the companies involved are concerned with determining the incidence of cancer in the families of job applicants. Also, in some cases, fertile women are excluded from such jobs.

More information is available on the situation in the United States, although many industries are reluctant to reveal their policies on genetic testing

for fear of generating adverse publicity. According to the series of articles mentioned earlier,[1] E.I. Du Pont de Nemours and Company and Dow Chemical Company are the principal proponents of genetic testing. It was reported in *The New York Times* that Du Pont gives pre-employment blood tests to all blacks in order to identify carriers of sickle cell trait. In addition, workers at Du Pont's Deepwater plant are tested for serum alpha-1 antitrypsin deficiency. 'The Times' also reported that Dow has conducted cytogenetic tests on workers exposed to vinyl chloride, benzene and epichlorohydrin. In addition, one article quoted Paul Kotin, the medical director of Johns Manville Corporation, as saying that the company has not yet begun an active cytogenetic program but is 'watching developments closely.' At this time, few other companies are known to conduct 'genetic testing', and it would appear that industry's use of pre-employment genetic testing is probably quite limited.

On the other hand, genetic monitoring is fairly widely used; for example, in the United Kingdom, ICI conducted a cytogenetic study of its vinyl chloride workers.[19] In the United States, Litton Bionetics has been involved with genetic monitoring for seven years; under contract, they perform cytogenetic analysis for chromosome aberrations and sister chromatid exchange and urine mutagenicity tests. A company official estimates that the firm is now testing about 600-800 human specimens per year.[20] Other laboratories in the United States have similar capabilities, and many companies (such as Dow) undoubtedly have their own in-house monitoring capability. In Ontario, few private laboratories offer Ames testing.

Issues Raised by Genetic Testing

Pre-employment Screening

Scientific Basis

There have been many scientific questions raised about the validity of pre-employment testing of workers. At present, it appears that there is little solid evidence linking any of the conditions described above with an increased risk of developing occupationally-related disorders. For example, Dr. Childs, chairman of a National Academy of Sciences study which examined genetic screening

programs, has stated that he could not conceive of any workplace (conforming to minimal hygienic standards) which would pose a problem to people with the sickle cell trait.[7] The consensus among most academic and government scientists seems to be that, while it might be useful to gather data on these conditions, routine screening is not indicated and, in general, there is no scientific basis for excluding anyone from employment on the basis of positive test results.

Policy Issues

The use of genetic tests during pre-employment medical examinations could raise the following questions related to public policy:

- Job Discrimination. Can workers with the 'wrong genes' or with a 'perceived' handicap legally be barred from a workplace?
- Occupational Exposure Standards. Should levels of hazardous substances be kept low enough to protect *all* workers or only those least susceptible? Labour groups feel strongly that the emphasis in occupational health should be on the elimination of workplace hazards rather than the elimination of susceptible workers. However, many advisory bodies such as the American Conference of Governmental Industrial Hygienists (ACGIH) set exposure limits designed to protect 'nearly all' workers, but not those most susceptible. Just how large a group should 'nearly all' be? In some cases, (e.g. ischemic heart disease and carbon monoxide exposure or fertile women and lead exposure) the 'susceptible' group may represent a sizeable portion of the work force.
- Burden of Proof. Should the government require employers to demonstrate that the medical tests they use are scientifically valid and are useful for the purpose for which they are administered?
- Racism in Hiring Practices. Because some mutant genes (e.g. sickle cell haemoglobin, G6PD) occur more frequently in certain racial groups, can employers subject members of these groups, but not other job applicants, to genetic screening tests?
- Will industry use pre-employment screening to eliminate susceptible workers, and then fail to protect those they do employ?

Many of these issues arise also in any type of health surveillance program. As such they are currently being reviewed by a new Task Force on the Role of Health Surveillance and Biological Screening in Occupational Health Programs, which has been set up by the Ontario Ministry of Labour's Advisory Council on Occupational Health and Occupational Safety.

Biological Monitoring

Scientific Basis

The use of 'genetic' types of biological monitoring has been more acceptable to the scientific community than pre-employment testing. Nonetheless, the fact remains that the clinical significance of these tests is not understood. For example, it is not known whether a particular individual with a high frequency of chromosome aberrations, or sister chromatid exchange (SCE), has an increased risk of developing cancer or producing offspring with birth defects. At this time, removing individual workers from their jobs because of positive test results is generally not warranted. These tests should still be considered as research tools.

Social and Policy Issues

The use of genetic monitoring of the work force could raise the following social and policy questions:

- Can or should such tests be mandatory for the workers involved?
- In view of the still experimental nature of such testing, should workers be used as guinea-pigs?
- What should be done with the test results? Do workers have the right to receive their own results? Does management have the right to receive workers' medical results?
- Should workers be removed from employment on the basis of these tests? If so, are they entitled to compensation?

US Approach to Genetic Testing

The US Department of Labor's 1974 carcinogen standard, in its sections on medical surveillance, states that 'before an employee is assigned to enter a regulated area, a pre-assignment physical examina-

tion by a physician shall be provided.[21] The examination shall include the personal history of the employee, family and occupational background, including genetic and environmental factors.' This statement has been interpreted by some industry officials as mandating tests to identify individuals who, because of genetic factors, might be more susceptible to harm from industrial exposures than the general working population. However, OSHA officials have explicitly rejected this interpretation: According to former Assistant Labor Secretary, Eula Bingham, 'exclusion of workers (from jobs) as a result of genetic testing runs contrary to the spirit and intent of the *Occupational Health and Safety Act* of 1970.'[22]

The position of OSHA and NIOSH (as of late 1981) seems to be that:

- current knowledge does not justify wide use of genetic traits (e.g. sickle cell trait, G6PD deficiency) to exclude workers from certain jobs;[23]
- there is no OSHA standard requiring genetic testing of any employee;
- if OSHA's limited requirements for gathering genetic information are used as a mandate to exclude workers on the basis of genetic factors, OSHA may act to amend or revoke those provisions.

Congress also appears to be concerned about the possible legal and ethical problems associated with genetic screening by industry; in October 1981, a sub-committee of the US House of Representatives held hearings on this issue.[24]

Conclusion

Mr. Anthony Mazzochi has predicted that 'the 1980s will be an era of genetic confrontation.'[1] While this may prove too strong a statement (for the moment, economic issues have eclipsed genetic issues), nonetheless, it is clear that the rapid advances in molecular biology and genetic technology will lead to increasingly sophisticated types of medical test procedures. To industries squeezed by rising costs, screening out susceptible workers may be more attractive than instituting expensive engineering controls. In the long run, it is important to ensure that the new genetic technology is used in ways that promote workers' health, rather than limit freedom.

Acknowledgement

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References

[1]Severo R. The Genetic Barrier: Job Benefit or Job Bias? *The New York Times*, February 3-6, 1980.

[2]Stokinger HE, Scheel LD. Hypersusceptibility and Genetic Problems in Occupational Medicine – A Consensus Report. J Occup Med 1973; 15: 564-573.

[3]Reinhardt CF. Chemical Hypersusceptibility. J Occup Med 1978; 20: 319-322.

[4]Cooper WC. Indicators of Susceptibility to Industrial Chemicals. J Occup Med 1973; 15: 355-359.

[5]Morse JO. Alpha$_1$-Antitrypsin Deficiency. New Eng J Med 1979; 299: 1099-1105.

[6]Nebert DW. Pharmacogenetics: Approach to Understanding Chemical and Biologic Aspects of Cancer. J Nat Can Inst 1980; 64: 1279-1290.

[7]US Institute of Medicine. Genetic Influences on Responses to the Environment. Washington, DC: National Academy Press, 1981.

[8]Hirschhorn K. Discussion Paper: The Role of Cytogenetics in Mutagenesis Testing. Ann NY Acad Sci 1975; 269: 12-15.

[9]Legator MS, Connor T, Stoeckel M. The Detection of Mutagenic Substances in the Urine and Blood of Man. Ann NY Acad Sci 1975; 269: 37-42.

[10]House R. The Ames Test – An Initial Appraisal. Occup Health in Ont 1980; 1: 2-11.

[11]Harding DH. Carcinogenesis – Interpreting Test Results. Occup Health in Ont 1980; 1: 34-44.

[12]Brewen JG. Cytogenetic Studies and Risk Assessment for Chemicals and Ionizing Radiation. In: McElheny UK and Abrahamson S, eds, Banbury

Report 1. Cold Spring Harbor Laboratory, Cold Spring Harbor, 1979: 97-115.

[13]Wyrobek AJ. Methods for Human and Murine Sperm Assays 1980. Unpublished Manuscript. Brusick D. Principles of Genetic Toxicology. New York: Plenum Press, 1980.

[14]Knudson AG. Persons at High Risk of Cancer. New England J Med 1979; 301: 606-607.

[15]King MC, Go RCP, Elston RC, Lynch HT, Petrakis NL. Allele Increasing Susceptibility to Human Breast Cancer May Be Linked to the Glutamate — Pyruvate Transaminase Locus. Science 1980; 208: 406-408.

[16]Kolata GB. Testing for Cancer Risk. Science 1980: 207: 967-969.

[17]Knudson AG. Current Status of the Knowledge on the Origin of Cancer and How Heredity and Environment Interact. In: Genetic influences in response to the environment. Washington, DC: National Academy Press, 1981: 35-39.

[18]Hanawalt PC, Cooper KC, Ganesan AK, Smith CA. DNA Repair in Bacteria and Mammalian Cells. Ann Rev Biochem 1979; 48: 783-836.

[19]Purchase IF, Richardson CR, Anderson D, Paddle GM, Adams WCF. Chromosomal Analysis in Vinyl Chloride-Exposed Workers. Mut Res 1978; 57: 325-334.

[20]Giss H. Litton Bionetics. Personal communication, November 1981.

[21]Federal Register 1974; 39: 3755-3797.

[22]Occupational Safety and Health Reporter 1980; 9: 859.

[23]Melius J. Speech to the American Society of Safety Engineers, June 23, 1980. Personal communication.

[24]Occupational Health and Safety Reporter 1981; 11: 422-423.

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Asbestos Identification and Sampling

Summary

This paper describes the methods of asbestos identification and sampling used by the Occupational Health Branch of the Ontario Ministry of Labour. X-ray diffraction analysis, polarized light microscopy and the standard MF technique are discussed in detail. Their limitations have also been pointed out. However, it is indicated that, at present, these are the most practical laboratory or field methods available.

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Introduction

Concerns have been expressed regarding the use of asbestos insulation material in non-industrial areas such as schools and other similar buildings where children may be potential victims. The long latency period of 30 to 40 years before the onset of clinical signs of asbestos-related disease makes exposure to children more alarming than a similar exposure to the industrial worker. In many countries, complete removals of asbestos-containing materials from these buildings have been carried out. However, total removal is not only expensive, but also extremely difficult. The alternative control methods chosen are encapsulation and enclosure. In some situations, a combination of all three is preferable. Nevertheless, much of the present-day concern relates to the actual fibre levels present in buildings where asbestos has been used as a construction material. Many recent studies have reported very low fibre concentrations, usually ranging from 0.2 to 0.005 fibres per cubic centimetre of air. In England, the Asbestos Information Committee accepts a non-occupational exposure level of 0.04 f/cc as a negligible hazard for a lifetime exposure. At these low concentrations, the potential for misjudgement and confusion in interpretation of the sampling results exists to a high degree. In addition, there is a substantial lack of unanimity as to how asbestos identification and sampling be approached and, in particular, how samples should be evaluated.

Many alternative techniques for the identification of asbestos varieties and sampling for airborne fibres have been suggested in the literature. In this paper, however, we have described only those methods which are currently in use by the Occupational Health Branch. In doing so, we have tried to present enough information for the average industrial hygienist to clearly understand our methods.

Properties Used in the Identification of Asbestos in Insulation Materials

Name	chrysotile	amphibole asbestos excluding crocidolite	crocidolite
Major X-ray diffraction peaks	7.3Å 3.7Å 4.6Å	8.4Å 3.1Å 3.3Å 2.7-2.8Å	8.4Å 3.1Å 2.8Å 2.7Å
Size	length of width ratio at least 3 to 1	length to width ratio at least 3 to 1	length to width ratio at least 3 to 1
Colour	colourless to grey	colourless to grey	pleochroic-greenish-blue
Form	bundles or aggregates of fibrils, generally wavy fibrils, diameter of fibrils less than resolution of the optical microscope i.e. 0.5 μm	bundles or aggregates of generally straight fibrils	bundles or aggregates of fibrils, generally straight fibrils
Cleavage	along the axis of the fibre	along the axis of the fibre	along the axis of the fibre
Refractive Index	$N\alpha$ = 1.49 to 1.55 $N\beta$ = 1.50 to 1.55 $N\gamma$ = 1.52 to 1.56 (intermediate refractive index < 1.59)	$N\alpha$ = 1.60 to 1.66 $N\beta$ = 1.61 to 1.70 $N\gamma$ = 1.62 to 1.70 (intermediate refractive index > 1.59)	$N\alpha$ = 1.69 $N\beta$ = 1.70 $N\gamma$ = 1.70 (intermediate refractive index > 1.59)
Birefringence (Interference Colour)	1st order grey to yellow	1st order to second order moderate	1st order may be obscured by colour of fibril
Extinction, elongation	parallel extinction length slow (positive sign of elongation)	parallel to oblique extinction, length slow (positive sign of elongation)	extinction angle 3°-5° sometimes parallel, length fast (negative sign of elongation)

Identification of Asbestos in Insulation Materials

The Occupational Health Laboratory of the Ministry of Labour, in co-operation with other Ontario ministries, has embarked on a program to identify asbestos in insulation materials used in public buildings. Over 2,000 buildings have been investigated and about 4,500 bulk samples have been collected and analysed. X-ray diffraction is used to confirm the presence of the asbestos minerals in the samples. Polarized light microscopy is used to classify the types of asbestos by their optical properties and fibrous morphology as chrysotile or amphibole asbestos. The latter includes *tremolite*, *cummingtonite-grunerite* (i.e. amosite), *anthophyllite*, *actinolite* and *crocidolite*. As crocidolite is considered to be the most hazardous form of asbestos, it is desirable to differentiate it from the other amphibole asbestos.

Initially, the sample is scanned by X-ray diffraction over the 2 theta range of approximately 5° to 40°. The d-spacing of the diffraction peaks are calculated and compared to the asbestos diffraction data published by the Joint Committee on Powder Diffraction Standards and to the diffraction patterns of known asbestos materials. Chrysotile and amphibole asbestos exhibit the same X-ray diffraction patterns as other minerals of the serpentine and amphibole mineral groups, respectively. Therefore, polarized light microscopy is employed to identify the asbestos by fibrous morphology as well as by their optical properties, which are listed in the following Table and described below. To perform microscopic examination, it is essential for the microscope to be equipped with a polarizer, analyser, gypsum plate and a rotating stage.

Refractive Index

Generally, it is tedious and time-consuming to determine the three refractive indices of each type of asbestos found in insulation materials. In most cases, it is sufficient to estimate, by the immersion test, the intermediate refractive index which lies between $N\alpha$ and $N\gamma$ of the asbestos fibre, depending on its orientation. When a chrysotile fibre, for example, is immersed in an oil with a refractive index of 1.59 and illuminated by plane polarized light, a dark line, known as relief, appears around the mineral fibre. It is caused by refraction of light at the boundary of the crystal and the oil. Its prominence is directly related to the difference between the index of the crystal and that of the oil.

Also, with the sub-stage diaphragm closed, and the focus of the microscope raised slightly, the Becke line, which is a bright line parallel to the crystal boundary, will appear. If the crystal index is lower than that of the oil, the Becke line moves out to the oil as the focus is raised. If the crystal index is higher than that of the oil, the Becke line moves towards the centre of the crystal. The behaviour of the Becke line is reversed if the focus is lowered instead of raised. In this way, chrysotile with its intermediate refractive index below 1.59, is differentiated from amphibole asbestos, which all have intermediate refractive indices above 1.59.

Fibre Morphology

One of the characteristics of asbestos minerals is that they have crystallized into bundles or aggregates of parallel small fibres or fibrils. When they are crushed, they split into small fibrils along the axis of the fibre. These fibrils are best observed under the microscope with crossed-polars. The bundles of fibrils of chrysotile are generally wavy and the diameter of a fibril is less than the resolution of the microscope. The fibrils of other asbestos are more or less straight and have comparatively larger diameters.

Among the asbestos minerals, crocidolite is the only one which is blue in colour. When examined under plane polarized light, it exhibits a subtle change of colour from blue to greenish blue as the microscope stage is rotated. This observed phenomenon is known as pleochroism, and it is due to the fact that crocidolite is an anisotropic crystal with three absorption axes, each of which absorbs different amounts of some wavelengths of light. However, the recognition of pleochroism sometimes may be obscured because of the thickness of the crocidolite fibre.

Parallel Extinction, Interference Colour and Birefringence

When an asbestos fibre is examined between crossed-polars, it becomes dark or in a position of extinction four times upon rotation of the fibre through 360°. This is due to the fact that when light enters an anistropic asbestos fibre, it resolves into three components with their vibration directions perpendicular to each other. At extinction position, the vibration directions of the components are at right angles with the planes of polarization of the polars and thus no light is transmitted. Chrysotile,

crocidolite and anthophyllite are said to have parallel extinction because they show extinction when their fibre axis is parallel to the plane of polarization of either polar.

On the other hand, when the fibre is rotated away from the position of extinction, its interference colour is observed. If it is illuminated with monochromatic light with a wavelength of λ, the interference colour will be the same as that of the monochromatic light used. Its brightness depends on the phase shift and different velocities of the ray components with respect to thickness of the fibre. The retardation (Δ) of the ray components with respect to each other is given as the product of the thickness of the fibre and the birefringence, which is defined as the numerical difference between the $N\alpha$ and $N\gamma$ refractive indices. The interference colour is at a minimum when $\Delta = n\lambda$ and at a maximum when $\Delta = n\lambda + \frac{\lambda}{2}$ where n = 1, 2, 3, etc. denoting first, second and third order.

However, white light is generally used for illumination and some other colour contained in the white light spectrum is observed. This is because certain colours or wavelengths are suppressed, while others are allowed to pass through, resulting in a composite interference colour. Those wavelengths suppressed are near or at a wavelength for which $\Delta = n\lambda$. In most optical mineralogy textbooks, a chart is usually included giving the interference colours to be expected from common minerals having birefringence ranging from 0.001 to 0.20 and the thickness of specimens varying from 0.01 mm or less to 0.06 mm.

As most of the small asbestos fibres and fibrils observed are below 0.03 mm in thickness, the interference colours of the asbestos fibres observed are fairly consistent from sample to sample. Chrysotile exhibits first order grey to yellow, amphibole asbestos first order to second order and crocidolite first order. However, the natural blue colour of crocidolite may obscure the interference colour. Thus, by comparison with the interference colour chart, the birefringence of the asbestos fibres may be estimated.

Elongation

Occasionally, crystal grains develop with an elongated habit and straight edges, and may resemble small needles as in asbestos. If such a crystal is

anistropic and the vibration direction of the slow ray component is parallel or about parallel to the long direction of the crystal, the crystal is said to have positive elongation or to be length-slow. When the vibration direction of the slow ray component is perpendicular to the long direction of the crystal, the crystal has negative elongation or is length-fast.

This optical property is identified by means of a gypsum plate which is made of clear gypsum cleaved to a thickness that gives a first order violet interference colour. When it is inserted into the light path of the microscope with crossed-polars, the whole field of view appears to be violet in colour. The gypsum plate is usually mounted in a metal holder so that the vibration direction of the fast ray component is parallel to the long direction of the holder and the slow ray component normal to the long direction of the holder.

All asbestos types, except crocidolite, are length-slow. Thus, when such a fibre with its axis parallel to the slow ray component is rotated to coincide with the fast ray component of the gypsum plate, the original violet colour of the fibre goes down in the spectrum to yellow. The rest of the field of view remains violet in colour. When the fibre is perpendicular to the fast component of the gypsum plate, i.e. the fast components of the fibre and the gypsum plate coincide with each other, the violet colour of the fibre goes up the spectrum to blue. Crocidolite is length-fast and it exhibits reverse colouration when viewed under the same conditions as above. Because of the natural blue colour of the crocidolite, a greenish-yellow is observed when its slow ray component coincides with the fast ray component of the gypsum plate. In this way, crocidolite may be differentiated from other amphibole asbestos.

Quantitative Assessment

After identification, the amount of each type of asbestos by volume is estimated visually under the microscope by the area it occupies with respect to all the particles, and is reported as one of the following:

a) none detected
b) less than five per cent by volume
c) five per cent to 25 per cent by volume
d) 25 per cent to 50 per cent by volume
e) 50 per cent to 75 per cent by volume
f) more than 75 per cent by volume

When asbestos is found in very small quantities (i.e. below five per cent), it is advisable to repeat the analysis several times to make sure that contamination is not responsible for the presence of asbestos.

Other Fibrous Materials

Glass fibres, mineral wool and cellulose fibres are generally found with asbestos in insulation materials. The glass fibres and mineral wool are isotropic and become extinct under cross-polars. If present in large quantities that may interfere with the analysis, the mineral wool can be removed partially or completely with diluted hydrochloric acid treatment. Cellulose fibres are anistropic, but exhibit uneven extinction during rotation. They may also be removed by ashing in a furnace at approximately 400°C for one hour.

Air Sampling in Public Buildings

For workplace evaluation, the present membrane filter method represents a substantial improvement in technique and it is reasonably satisfactory. On the other hand, for non-workplace situations, especially those where very fine fibres could exist, the conventional method may be unsatisfactory. However, the next available method is time-consuming and requires considerable expertise in technique.

To obtain the resolution required to see all asbestos fibres and to be able to identify them, it is necessary to resort to electron microscopy. Electron microscopes, though not exactly uncommon, are not as readily available as the conventional and optical microscopes. It is very difficult, also, to find people familiar with electron microscopy who are also able or interested in counting asbestos. This limited analytical capability creates a substantial dilemma because evaluation of exposures must be done. All air tests made during removal of insulation, and reported in the literature, involved the use of membrane filter (MF) technique and phase-contrast microscopy despite the method's inability to distinguish between asbestos and other fibres and limited resolution. This, in our opinion, was mainly due to the practicality and simplicity of the technique. In Ontario, the MF method for sampling and evaluation by phase-contrast microscopy has also been used for assessing personal exposure for basically the same reasons as stated above. Durations of sampling and counting of microscopic fields have varied depending

on the expected fibre concentrations. A detailed description of the method is outlined below.

Province of Ontario Standard Method

A measured volume of air possibly containing asbestos fibres is filtered through a cellulose ester membrane filter of specified pore size held in an open-faced holder. A section of the filter is then mounted on a microscope slide containing a drop of 'clearing solution', which transforms the filter to a transparent optically homogeneous gel. The slide is mounted on the stage of a phase-contrast microscope, and the fibres are counted at 400 to 450 times magnification.

Sampling Equipment

a) A battery-operated portable pump which should:
   i) be capable of delivering for a full workshift, two or more litres of air per minute; the maximum deviation from the prescribed flow rate should not exceed ±5% and the pump should be equipped with a pulsation damper;
   ii) be intrinsically safe, i.e. be certified by an accepted agency as safe for use in potentially explosive atmospheres;
   iii) include a calibrated flow meter, volume meter or a mechanism for maintaining a prescribed rate;
   iv) have an on/off switch and flow rate control mechanism, which are as tamper-proof as practicable.

b) A 37 mm inner diameter filter holder which is:
   i) capable of being used for open-faced sampling;
   ii) equipped with an adapter which provides a leak-proof fit for connecting flexible tubing.

c) Cellulose ester (membrane) filters, 37 mm in diameter and 0.8 micrometre (um) in pore size.

d) Cellulose filter support pads, 37 mm in diameter when required.

e) A sufficient length of flexible polyethylene tubing as necessary, with a minimum wall thickness of 1.6 mm and an inner diameter which provides a leak-proof connection to the filter holder and portable pump adapter.

Analytical Requirements

a) An optical microscope with the following features:
   i) a binocular head;
   ii) 10X Huygenian or equivalent eyepiece;
   iii) illumination with adjustable intensity;
   iv) Patterson Globe and Circle or equivalent reticle;
   v) a mechanical stage;
   vi) a phase-contrast condenser with a numerical aperture, equal to or greater than that of the objective;
   vii) 40-45X phase-contrast achromatic objective with a numerical aperture between 0.65 and 0.75;
   viii) a phase ring centring telescope or Bertrand lens;
   ix) a stage micrometer with 0.01 mm subdivisions; a stage micrometer.

b) Glass microscope slides having 2.5 × 7.5 cm dimensions with one end frosted.

c) Coverslips for covering the filter on the microscope slide (2.2 × 5 cm size and about 0.17 mm thick).

d) Scalpel for cutting wedge-shaped portions from the filter.

e) Fine-tipped tweezers for handling the filter.

f) Solution for preparation of the sample, made by mixing dimethyl oxalate in the 1:1 ratio by volume. To this solution, 0.05 g of cellulose ester filter per millilitre is added. Stir gently with a clean glass rod. Allow the mixture to stand until a homogeneous solution with a refractive index of approximately 1.47 is obtained. The solution must be discarded after three months or when it becomes turbid. A fresh solution must then be made. The reagents used must be reagent grade, free of particles and colour, and conform to the specifications of the American Chemical Society Committee on Analytical Reagents.

Sampling Procedure

a) The pump battery pack should be fully charged before use in any workshift. If more than one shift is being sampled, fully charged batteries should be substituted for the discharged ones.

b) Flow meters, volume meters or constant flow devices on the pumps must be calibrated at 2.0 litres per minute (Lpm) by using a primary standard such as a bubble meter or spirometer by the procedure recommended in the instructions for using the primary standard apparatus, with a representative filter holder and membrane filter in line:
   i) after not more than 40 hours of operation; checked after each workshift;
   ii) after receiving unusually harsh or potentially damaging treatment;
   iii) after being disassembled for maintenance.

Preparation of Filter Holders

a) Assemble the filter holders in a clean environment prior to the initiation of sampling.

b) Prepare each filter holder by the following procedure:
   i) Use only clean filter holders and handle the support pad and filter with tweezers. Place a filter support when necessary and a cellulose ester filter in the base of the holder.
   ii) Assemble the holder and seal the outlet and inlet ports.
   iii) Ensure that the joints of the filter holder are sealed.
   iv) Identify the sample by labelling the holder with an appropriate sample number.

Sampling

a) Assemble the sampling train by fixing one end of the flexible tubing to the inlet port of the pump and the other end to the adapter on the outlet port of the filter holder.

b) Check for air leaks in the sampling train by turning on the pump and sealing the inlet port of the holder. The flow indicator on pumps with flow or volume meters should drop to the zero position and oscillate slightly; on pumps with constant flow devices, however, the pumping speed should increase to a maximum. If this does not occur, find the faulty component and either repair the air leak, if possible, or replace the component.

c) Attach the pump to the worker's belt or place it in his pocket; draw the flexible tubing over the

shoulder and fix the holder as near as possible to the breathing zone, ensuring that the face of the holder is pointing downward. The equipment should be fitted so as to interfere as little as possible with work.

d) Check that all equipment is properly assembled, remove the face portion of the holder so that open-faced sampling can be performed, and switch on the pump. Allow the flow rate to stabilize, then adjust the rate to two litres per minute. Pumps with constant flow devices should not be reset after the flow rate control mechanism has been adjusted to deliver air at 2 Lpm, by comparison with a primary standard method.

e) Note the following information for each sample:
   i) Name of worker
   ii) Clock number of worker
   iii) Model and serial number of the pump
   iv) Date of sampling
   v) Company name
   vi) Equipment calibration date
   vii) Sample number on the filter holder
   viii) Air flow rate at initiation of sampling
   ix) Time of initiation and termination of sampling

f) Ensure that for sampling performed during any particular survey, two blank filters are prepared in the same manner as the sampling filters. These filters should remain in sealed holders during the sampling. Label these as blanks and send along with samples for analysis.

g) To estimate the proper sampling times for statistically reliable fibre counts, consideration should be given to microscope field area, pump flow rate, average expected airborne fibre concentrations, counting rule range of 20 to 100 fields, adequate fibre density to yield a minimum count of 0.1 fibre per field and background airborne particulate level. An optimum fibre density of about one to five fibres per field is recommended to minimize the counting errors.

In order to get an idea of airborne fibre levels in a workplace, it is suggested that long and short interval samples should be taken. In this way, if long

interval samples are too populated with fibres to count, the short interval ones can be used to calculate the actual fibre concentration.

The following formula may be used to estimate the minimum sampling time:

$$\textit{Sampling time: } t = \frac{f.A.}{F.a.C.\ 1{,}000} \text{ minutes}$$

where F = flow rate of the sampling pump
f = number of fibres/field, desired
A = effective collection area of filter, mm^2
a = microscope field area, mm^2
C = fibre concentration, fibres/cm^3

h) Sufficient number of samples should be taken to obtain a time-weighted average concentration.

Fibre Counting Procedure

1) Calibration of the Area of the Microscope Field of View

a) The Patterson reticle must be calibrated with a stage micrometer. Each combination of eyepiece and objective used with the reticle must also be calibrated at least once:
   i) when the microscope is first received;
   ii) when new objectives or eyepieces are installed;
   iii) after the microscope has received a major servicing.

b) Follow the procedure below to perform a proper calibration of the area of the reticle:
   i) With a 10X objective in the microscope, place the stage micrometer on the mechanical stage, focus on the millimetre scale and centre the image.
   ii) Change to the 40X objective and adjust the first millimetre scale division to coincide with the left boundary of the Patterson Globe and Circle reticle.
   iii) Read the micrometer position best coinciding with the right boundary of the reticle. Estimate any portion of the final division. This measurement represents the length (L) of the reticle.
   iv) Give a 90° rotation to the eyepiece (with

reticle) and adjust the first millimetre scale division to coincide with the left boundary of the Patterson reticle.

v) Read the micrometer position best coinciding with the right boundary of the reticle. Estimate any portion of the final division. This measurement represents the width (W) of the reticle.

vi) Calculate the area (a) of the reticle: $a = L \times W$ mm^2.

vii) Calculate the circle diameters. The #25 circle diameter is 0.1 × (reticle length). The circle diameters are proportional to the ratio of their numbers. Thus the #20 circle diameter is 20/25 or 0.8 times the #25 circle diameter.

Example:
If length = 0.112 mm and width = 0.051 mm
Microscope Field Area = 0.112 × 0.051 = 0.0057 mm^2

Circle No.	Diameter (μm)
25	11.2
20	8.95
15	6.72
12.5	5.60
10	4.48

Preparation of Slides

a) Perform all work in a clean environment. Clean slides, coverslips and all tools with lens tissue, and lay slides on a clean surface with frosted end facing upward.

b) Label the frosted glass part of the slide with the same sample number as the filter holder containing the sample filter.

c) Using a glass rod, stir the mounting solution vigorously to ensure homogeneity; apply a drop to the centre of the slide and spread this solution into the approximate shape and size of the wedge cut from the sample filter.

d) Disassemble the holder to expose the filter and make two cuts from the centre of the filter to the perimeter. The wedge cut is to be approximately *one eighth* of the total surface of the filter.

e) Transfer the wedge to the solution on the slide, exposed side facing upward, with clean tweezers.

f) Carefully place a coverslip over the wedge. *Do not* press or reposition the coverslip once contact with the solution has been made.

g) Slides must be left for at least one hour after preparation before the counting begins. If counting has not commenced within 48 hours, the slide must be discarded.

Counting of Fibres on the Slides

a) Position the slide on the mechanical stage with the centre of the wedge under the objective lens and focus on the sample.

b) Move the slide to a position near one side of the wedge and select a random field of view, i.e. the area of the reticle, by looking away from the microscope and advancing the slide in one direction with the mechanical stage control.

c) Use the fine focus adjustment to scan different focal planes of the filter surface to obtain an accurate count in each field of view.

d) Use the following criteria for counting of fibres for each field of view:
   i) Avoid counting fields on the edge of the filter;
   ii) If a mass of material covers a significant portion of the field of view, reject the field and select a new one (do not use the discarded field in the calculation).
   iii) If the filter is too heavily loaded with fibres, i.e. more than 25 fibres are present in each field of view, do not count this filter, and use only those samples obtained over short durations, if possible, to obtain an estimate of the fibre concentration.
   iv) Use the calibrated circles of the reticle to measure the length and diameter of fibres with an aspect ratio of 3:1 or greater, with a length greater than five um, and with a diameter smaller than three um. Use the calibrated circles of the reticle to measure the length and diameter of fibres; measure curved fibres along the curve to estimate the total length.

v) Count the fibres positioned entirely within the borders of the field of view as one fibre.
vi) Count the fibre with one end outside the field of view as half a fibre and *do not* count the fibre with both ends outside the field.
vii) A bundle of fibres is counted as one fibre unless both ends of the bundle can be clearly resolved.

e) Record the total number of fibres in each field of view.

f) Select a new field of view by repeating part (b); when the opposite side of the filter has been reached, advance the other directional control of the mechanical stage and follow a path roughly parallel with the first series of fields selected. Following this zig-zag pattern will ensure that a maximum area of filter is covered.

g) Stop counting only when a minimum of 20 fields containing 100 or more fibres have been counted or when a total of 100 fields have been counted.

Quality Control on Counting and Preparation

a) Count the blank filters first; if these blanks contain more than three fibres in 50 fields of view, the entire air sampling procedure must be examined for sources of contamination. Repeat air sampling.

b) One sample in every 20 or one sample per batch, whichever is less, selected at random, must be recounted by the same person. If the per cent difference between the two counts is greater than 30 per cent, two additional samples from the batch must be recounted. If these two also show a variation greater than 30 per cent, all samples in the group of 20 or the batch must be recounted, and the mean results of the two separate counts must be reported for this group of samples. (Note: If the difference is greater than 60 per cent on these samples, the sampling must be repeated).

c) One sample in every 20 or one sample per batch, whichever is less (i.e. not the same sample as selected for recounting), selected at random, must be reprepared from a freshly cut section of

filter and recounted by the same counter. If the difference between the two counts is greater than 50 per cent, two additional samples from the batch must be recounted. If these two also exhibit a difference greater than 50 per cent, all samples in the group of 20 or the batch must be recounted, and mean results of the two separate counts must be reported for this group of samples. (Note: If the difference is greater than 90 per cent on these samples, the sampling must be repeated).

Calculation of Results

Results of mean fibre count per field of view can be converted to concentration of asbestos fibres in the air sample by using the following equation:

$$C = \frac{855 \times (A - B)}{1000 \times T \times F \times a}$$

where C = the airborne fibre concentration in units of fibres per cubic centimetre
A = the total number of fibres counted per wedge divided by the total number of fields of view
B = the mean of the total number of fibres counted per wedge on the blank filters divided by the total number of fields of view observed
855 = the collecting area of the filter for a 37 mm diameter filter with an effective diameter of 33 mm in mm^2
1000 = the factor for converting litres to cubic centimetres
T = sampling duration in minutes
F = flow rate of the sampling pump, litres per minute
a = the area of the field of view of the microscope in mm^2

Note: Correct the volume of air sampled for pressure and/or temperature variations, if necessary.

Sufficient area samples must also be taken at all work locations.

Limitation

In a workplace atmosphere known to contain asbestos, all fibres with a length to diameter ratio of three to one or greater, and a length greater than

five micrometres and a diameter smaller than 3 micrometres, are, in the absence of other information, considered to be asbestos fibres and are counted as such.

Asbestos Reference Material

The following are the asbestos reference materials than can be used for the identification of asbestos:

1) UICC* Chrysotile;
2) UICC Amosite;
3) UICC Anthophyllite;
4) UICC Crocidolite;
5) Tremolite M37789 (kindly provided by Dr. F. Wicks of the Royal Ontario Museum).

*Timbrell V. Characteristics of International Union Against Cancer (UICC) Standard Reference Samples of Asbestos; 28-36, Proceedings International Conference on Pneumoconiosis, Johannesburg, 1969.

Alternatively, 25 mm filters and filter assemblies can be used as long as the appropriate adjustments are made, particularly for filter collecting area and wedge cut size.

Range of Detection Limits

Analytical procedures used by the ministry will be reviewed periodically and, if necessary, revised.

The range of the MF method is dependent on air volume sampled, microscope field area and background dust levels. An example of the range and sensitivity obtained by varying the sample volume and the microscope field area is given below:

Flow Rate	Microscope Field Area	Detection Limit Lower (8 hour sample)	Detection Limit Upper (15 minute sample)
1.7 1 pm	0.003 mm^2	0.4 f/cm^3	60 f/cm^3
1.7 1pm	0.006 mm^2	0.2 f/cm^3	30 f/cm^3

NIOSH recommends the minimum fibre density of 10 fibres per 100 fields for reliable quantification. Based on this, the lower limit of detection is compu-

ted to be 0.1 f/cc for a flow rate of 2.5 Lpm and field area of 0.003 mm^2 and sampling time of two hours. However, by increasing the time of sampling, the detection limit could be lowered further. One of the limiting factors in the industrial environment is the presence of other dusts which may overload the filter, thereby masking the fibres. In the general environment where the other dusts are almost non-existent, the sampling time can be conveniently increased resulting in order of magnitude lower detection limits, e.g. .04 f/cc.

Conclusions

We have presented the techniques used by the Occupational Health Branch to determine asbestos in insulation materials and airborne asbestos concentrations during insulation removal and/or disturbance. For bulk materials, X-ray diffraction analysis is used to confirm the presence of amphibole and serpentine minerals by their crystal structures, and polarized light microscopy is used to determine the presence of asbestos by the optical properties such as refractive index, fibrous morphology, pleochroism, extinction, interference colours and signs of elongation. For air samples, the standard MF technique and phase-contrast microscopy are used. We are fully aware of the criticism of the MF technique, and the Occupational Health Branch has undertaken several projects to improve the MF technique, and to incorporate electron microscopy, X-ray fluorescence microanalysis in the analysis of airborne asbestos.

Delly JG, McCrone WC. The Particle Atlas. Vol. 2. 2nd edition. Michigan: Ann Arbor Science Publishers Inc., 1973.

Kerr PF. Optical Mineralogy. 4th Edition. McGraw Hill Book Company, 1977.

Khati B. Asbestos Fibre Counting by Optical Method (A Training Manual for New Counting.) Internal Report. Occupational Health Branch. Ontario Ministry of Labour. May 1980.

Morse SA, Stolber RE. Microscope Identification of Crystals. New York: The Ronald Press Company, 1972.

Rajhans GS, Sullivan JL. Asbestos Sampling and Analysis. Michigan: Ann Arbor Science Publishers Inc., 1981.

Wahlstrom EE. Optical Crystallography. 4th Edition. New York: John Wiley and Sons Inc., 1974.

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Role of a Social Worker in a Steel Industry*

Summary

This paper outlines the working experiences of an industrial social worker in a non-unionized steel industry.

The description includes role, sources of referral, types of problems, types of service and the importance of confidentiality.

Individual employees, couples and families are seen for a variety of difficulties and concerns.

Introduction

This survey was conducted by a large steel industry in Hamilton, Ontario. This non-unionized company employs approximately 11,500 people.

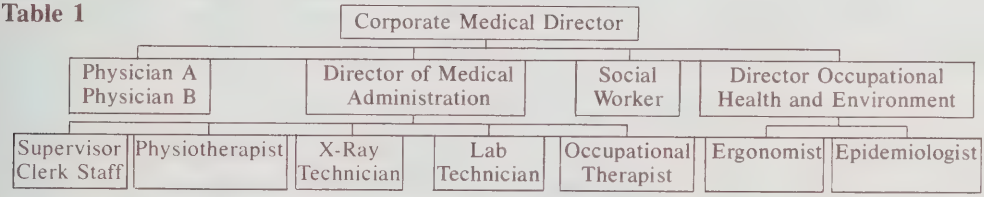
A breakdown of the employee population is as follows:

Management	2 per cent
Staff	10 per cent
Hourly	88 per cent

Social Worker

The Medical Department staff totals approximately 50 employees. A description of the Medical Department is illustrated by the organization chart in Table 1.

Table 1



I have been employed as a full-time social worker in the Medical Department since 1975. My office is in Medical and on a professional level I report to the corporate medical director.

My involvement centres on the clinical aspect of social work and I see individual employees, couples and families, depending on the circumstances.

My specific role includes:

i) counselling
ii) assessment
iii) referral
iv) consultation
v) supervisory training

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*Presented at the 54th Joint Quebec-Ontario Conference, 'Occupational Medicine – A Factor in Fulfillment for the Worker', Montreal, November 13, 1981.

Referrals

During the past five years (1976-1980), my referrals have come from a variety of sources:

i) physicians
ii) nurses
iii) self-referrals
iv) foremen/supervisors
v) Personnel Department
vi) family members
vii) outside agencies

A more specific breakdown is shown in Table 2.

Table 2 **Source of Referral**

Year	1976	1977	1978	1979	1980
Total Number of Referrals	107	116	119	202	241
Medical Department (Physicians, Nurses, etc.)	81%	54%	58%	43%	39%
Self-referrals	13%	26%	23%	36%	44%
Foremen/ Supervisors	4%	13%	12%	15%	10%
Personnel Department	2%	4%	3%	4%	4%
Family Members	0%	2%	1%	1%	3%
Outside Agencies	0%	1%	3%	1%	0%

Employees know they can come over to the Medical Department on company time and still receive full pay.

However, it is interesting that employees generally prefer to come in on their own time. This could be before an afternoon shift, after a night shift or even on a day off.

It must be emphasized that I see not only problem employees, but employees with problems. There is

an important distinction here in that many self-referrals are from employees who have excellent work records, but wish to discuss a personal concern.

There are also, realistically speaking, some people who would choose to have nothing to do with social work services, especially in the work setting, preferring either to see no one or, perhaps, to seek help through other channels more familiar to them.

During the last five years, there has been a steady increase in the number of self-referrals. In 1980, over 50 per cent of my caseload came from foremen, supervisors and self-referrals.

It is felt that the significant increase in self-referrals has been due, in part, to the various articles and announcements that have appeared on the radio, as well as the two company publications which every employee receives at home on a monthly (approximate) basis.

Another possible factor in the increase is 'word-of-mouth'. In other words, employees mention to others that they have been to see the social worker. Employees (self-referred) do come in and sometimes say, 'I know you've seen so-and-so and I thought I'd come in and see you.'

The average age of employees that I see is between 33 and 34 years. The male/female ratio is proportionate to the employee population, that is, the company employs about 90 per cent men and 10 per cent women.

The distribution is shown in Table 3.

Table 3 **Age and Sex Distribution**

Year	1976	1977	1978	1979	1980
Average Age	34 yr.	34 yr.	33 yr.	33 yr.	33 yr.
Oldest	63 yr.	59 yr.	62 yr.	61 yr.	61 yr.
Youngest	18 yr.	17 yr.	18 yr.	19 yr.	18 yr.
Male	94%	96%	88%	89%	86%
Female	6%	4%	12%	11%	14%

Confidentiality

The success of an industrial social work program hinges upon the very important aspect of confidentiality.

The elements of respect and trust must be established from the outset. If they are betrayed, the program will prove meaningless.

In cases where the Medical Department has to confer with the Personnel Department, certain procedures are followed. For example, if, for medical reasons, an employee can no longer do his own job and requests a transfer to another job, the Medical Department will support the request in writing to the Personnel Department.

However, specific reasons are not given, but phrases such as 'medical condition' or 'medical reason' would be used to cover a request for a job change.

For instance, the actual medical reason may be epilepsy, a skin rash, diabetes or asthma, but this would not be specifically stated. This information is strictly confidential and stays within the confines of the Medical Department.

Problem Identification

First, let me say that most of us experience some anxiety or apprehension in going to discuss a problem — personal or otherwise.

This is specifically true in the field of mental health. Physical problems are socially acceptable, but mental health concerns are still likely to carry a stigma — although this is probably not as pronounced as it used to be.

Mental health problems are common to all human beings at one time or another as we pass through the various phases of our lives. Stress, anxiety, fear and frustration are terms most of us can identify with on a personal level. How well one copes depends on one's ability to problem solve, but this is often easier said than done.

It is possible to get bogged down in a problem solving dilemma, no matter how capable one is, and some outside counselling may be necessary. Some people never learn how to problem solve effectively and no amount of counselling seems to help. Fortunately, it has been my experience that most people have the capacity to solve their problems either on their own or with some outside assistance.

When a problem arises that is hard to deal with, what does a person do, especially if the resultant

anxiety is interfering with day-to-day functioning of the family, marriage and job?

Having a social worker on staff is a service provided by the Medical Department to help employees and their families to deal with some of these issues. At least, it's a place from which to start.

It is quite surprising how many individuals have no family physician and how many have no idea of what helping resources are available in the community or how to link up with them.

Once people have made a decision to seek help, it is often difficult for them to walk into my office, sit down and start talking about their emotional pain. It is very important to make them feel comfortable through courtesy and respect.

Sometimes, employees may not be fully acquainted with the social work service and ask for a brief explanation, which I give them. I also emphasize the confidential nature of the interview, thereby establishing a bond of trust.

Most people are very open and honest in talking with me, but if someone is uncomfortable in giving me information, I don't push it.

There is a broad spectrum of concerns that I have been asked to deal with, including:

— job
— marriage
— family
— separation
— divorce
— anxiety
— stress
— love affairs
— depression
— shop lifting
— gambling
— loss of a loved one
— attempted suicide
— alcoholism
— drug addiction
— physical disabilities
— rape
— homosexuality
— incest
— legal concerns
— financial concerns

Table 4 indicates the distribution of these problems within the caseload.

Table 4 **Problem Identification**

Year	1976	1977	1978	1979	1980
Total Number of Referrals	107	116	119	202	241
Social (marital, separation, divorce, family, job, etc.)	65%	53%	53%	44%	45%
Mental illness (alcoholism, drug addiction, anxiety, depression, etc.)	27%	41%	41%	46%	47%
Medical (physical disabilities, finding physicians, etc.)	3%	3%	5%	5%	4%
Legal (arrests, custody, civil suits, etc.)	3%	0%	0%	3%	3%
Financial (debts, loans, garnishments, etc.)	2%	3%	1%	2%	1%

[1]Based on the model by Andrew Weissman.

The problems that have surfaced are not specifically characteristic of this company, but reflect human behavioural concerns that can, and do, occur in most societies.

It is of interest to note that when a problem involves a pending legal charge, some individuals may seek assistance so that a request for some sort of character reference or documentation of a successful therapeutic outcome can be obtained to coincide with the later court appearance.

They may comply with the therapeutic goals, but as soon as they have the letter, which they think will help in court, they may terminate therapy.

Of course, this may not happen, but I mention it as a point to keep in mind when assessing these situations.

Types of Service

Each year there has been a steady increase in the total number of referrals.

Some of the situations I handle directly, but in the majority of situations I draw upon not only my own expertise, but the resources of the community as well as the company.

Although I see individuals, couples and families, I also refer to outside resources whenever necessary, and always with the knowledge and permission of the party concerned.

Community resources include family therapy centres, psychiatrists, single parent groups, as well as legal and financial facilities, to name a few.

Company resources include recreation facilities, retirement counselling, credit union and credit counselling, payment of night school courses as well as the Temporary Absence Program.

Occasionally, an anonymous phone call is received. The person may refuse to give his or her name or come in for an interview, but wants some information regarding a problem.

Table 5 illustrates the distribution and types of service offered.

Table 5

Types of Service

Year		1976	1977	1978	1979	1980
Total Number of Referrals		107	116	119	202	241
Type	**Explanation**					
Direct	Straight counselling i.e. no involvement of additional resources	51%	28%	12%	2%	9%
Semi-Direct	a) Combination of counselling and utilization of community resources	28%	46%	55%	67%	66%
	b) Combination of counselling plus utilization of company resources.	14%	25%	29%	21%	20%
Indirect	Referral to resources within the community without direct ongoing involvement of industrial social worker.	7%	1%	4%	10%	5%

Discussion

A very common misconception is that most problems among employees are alcohol related.

Although this may be true for some work environments, it has not been validated in my experience as an industrial social worker.

In fact, only about 20 per cent of the referrals I receive are for alcoholism. Nevertheless, alcoholism is treated with utmost concern, and a specific treatment program has been established for many years.

The authors of 'Social Work in Industry' point out '... the main problems of employees have been related to the family, alcohol, the law, marriage, finances and drug abuse.'[2] I, too, can substantiate that a broad spectrum of problems have surfaced as described in the list of presenting problems and concerns outlined in this paper.

I would emphasize that it pays positive dividends for employees and their families to become fully acquainted with their company's Employee Assistance Program and what this means in terms of services and benefits available to them.

'Many scholars have shown that the workplace often constitutes an informal but definable helping and support network for its participants! Furthermore ... as family and personal problems can influence an individual's work life, so too, aspects of a person's work life can influence others in his or her family.'[3]

One of the main goals of our program is based on a preventive approach to problem solving for the employee population.

When a problem arises that plays havoc with our emotional well-being, better to reach out and get assistance than to wander around in a preoccupied and withdrawn state of mind. Personal safety as well as the safety of others is at stake. Also, problem solving at the early stages is less difficult than at a more advanced level.

In my experience as an industrial social worker, I have found that some employees may return at a later date wanting some form of assistance for another concern and, also, as mentioned earlier, that some of my referrals, especially self-referrals, have come by 'word-of-mouth'. This can be a significant catalyst in terms of the self-referred employee.

Another observation is that supervisors are crucial in promoting the success of the program. That is to say, if they have referred an employee and the

results are favourable, they are quite likely to refer again if the need arises and also to speak well of the program to fellow supervisors.

Acknowledgement

With sincere appreciation to Dr. E.S. Gibson, Director, Occupational and Environmental Health, for his helpful assistance.

References

[1]Weissman A. A Social Service Strategy In Industry, Social Work September 1975; Vol. 20, No. 5, 401-403.

[2]Skidmore RA, Balsam D, Jones DF. Social Work in Industry, *Social Work*, May 1974; Vol. 19, No. 3, 282-286.

[3]'Meeting Human Service Needs in the Workplace: A Role For Social Work'. Report of the Wingspread Conference April 1-4, 1979, sponsored by the Columbia School of Social Work, The Hunter College School of Social Work and the Council in Social Work Education, New York.

G.R. Wright, P.Eng., Ph.D.

Overview of VDT Ergonomics*

Summary

Visual Display Terminals (VDTs) are becoming increasingly evident in offices and other work environments. The operators' attitudes to this technology is influenced by their expressed concerns about a possible radiation hazard and the documented examples of visual discomfort, general physical discomfort and psychosocial discomfort. The ergonomic approach to avoiding these problems promotes the comfort and efficiency of the operator by assessing the characteristics of the user, the equipment, the work environment and the work tasks the user wishes to perform. However, true prevention requires consideration of these areas before, not after, the VDT is introduced into the workplace.

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Introduction

The ergonomist has two main objectives when selecting and/or designing equipment, workplaces or work environments. The first is to ensure the well-being and safety of the user; the second is to allow the individual operator to make the best use of his or her skills and abilities.

The primary ergonomic requirement for a visual display terminal is that it should perform all of the functions required of it.[1] To ensure that this requirement is met, designers and purchasers of visual display terminals (VDTs) must consider not only the equipment but also the work environment, the characteristics of the user and the tasks the user wishes to perform.

While it is easy to specify in these general terms 'what' should be done, it is more difficult to specify the 'how', for in spite of an extensive literature on the subject of computers, comparatively little has been written about the people who use VDTs or the conditions under which they are used. Thus, to gain an understanding of how an ergonomic approach can contribute to the well-being of VDT operators, it is useful to look first at the concerns most frequently mentioned by the users.

Concerns of VDT Operators

The prospect of working with VDTs can be a source of anxiety. For some people, the anxiety stems from the fear of job insecurity and the prospect of redundancy.[2] Many, however, fear that working with a VDT might pose some health or safety risk.[1] Initially, there was concern about a possible radiation hazard.[3] Lately, more operators are expressing concern over possible visual discomfort,[4] general physical discomfort and psychosocial discomfort.

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Visual Discomfort

General experience, as well as field studies, indicate that some operators report various types of eye discomfort.[5-8] The most frequently reported complaints related to eye fatigue or eye irritation are: general eye discomfort, eye strain, burning and irritated eyes, lachrymation and red eyes. The complaints related to impaired accommodation are: difficulty in fixing characters and blurring or double vision.

Physical Discomfort

The most frequently mentioned symptoms of physical discomfort reported by VDT operators are: neck pain, neck pain into the shoulders, sore shoulders, pain in the upper back, pain in the lower back, pain in the arms and legs, sore wrists, hand cramps and loss of arm strength.[8-10] The seriousness of these 'almost daily pains' should not be underestimated, for in Hunting *et al*'s (1980) study, 20 per cent of the operators had visited a medical doctor during the last year for treatment of arm and hand impairments.

Psychosocial Discomfort

The introduction of new technologies such as VDTs into the workplace can result in a broad range of changes in the organizational and technical structure of work. These changes may contribute to feelings of discomfort, either at the social level or the psychological level.[1] Social discomfort is characterized by the situation in which the individual's job within the organizational structure and the results of his or her work are beyond the individual's control. Thus the individual may feel like 'a small cog in the machinery of a large organization' and may no longer feel master of the job, but rather mastered by the job. At the psychological level, simple, repetitive work, lacking interest and not fully utilizing the operator's capabilities can lead to individual feelings of powerlessness, doing a job that is not important, being stressed yet isolated within the working environment and no longer being able to reach personal goals and expectations.[1,8,9]

Preventive Measures

The concerns mentioned above are an indication that adverse health effects may result from working with video display terminals. However, the operator's comfort and well-being can be enhanced through consideration of the characteristics of the user, the equipment being used, the work environment and the work tasks to be performed.

Characteristics of the User

Individual differences in body dimensions and in visual abilities are two important user characteristics to consider.

Body Dimensions

The anthropometric matching of the workplace to the operators of VDTs requires specific consideration of working level, desk and seating heights and the provision of foot rests. Working level is defined as the distance between the underside of the thighs and the palms of the hands when the forearm and hands are horizontal. The working level should fall in the range corresponding to the lower fifth percentile limit for the female population and the upper 95th percentile limit for the male population (220 to 250 mm respectively). Generally, clearance from the underside of the desk to the underside of the thighs should be between 170 and 200 mm. If the thickness of desk tops is approximately 20 mm, both requirements are satisfied only when the height of the keyboard is 30 mm.[1] The variables of desk height, seating height and height of the foot rest are inter-related, for fixing the height of one of them requires that the remaining two variables be adjustable. Practically, it is more sensible to fix the desk height, then adjust the seating and foot support heights. A floor to desk-top height of 720-750 mm with a minimum free height of 650-690 mm is recommended.[1]

Visual Ability

Although many factors influence visual ability,[11] two of the more important considerations for VDT operators are uncorrected eyesight deficiencies and aging. Very few people have perfect vision; common defects are long or short-sightedness, decrease in accommodation ability and astigmatism.[1] Indeed, it is estimated that 20 per cent to 30 per cent of the

working population have uncorrected or inadequately corrected visual defects. This is due, in part, to the natural deterioration in visual function as a consequence of aging. For example, between the ages of 20 and 60 the visual acuity of even a normally sighted individual is reduced by about 25 per cent.[12]

Fortunately, it is possible to correct for this reduction in visual acuity. The use of glasses with monofocal lenses poses few problems for VDT use. However, age also has a marked effect upon the ability of the eye to accommodate to different visual distances.[11] In this case it is important that if a VDT operator is required to wear glasses, lenses are chosen which provide a sufficient range of focus. The speed of accommodation also decreases rapidly with age;[1] because of this change, the VDT keyboard and screen and the source document should be situated at roughly the same distance from the user's eye.

Equipment

Visual Displays

Readability of the visual display requires consideration of design, formation and stability of the character images. A '7 dot' character height is usually considered to be a minimum requirement. Most editing terminals have a character height of '9 dots' or more. The optimum ratio of width to height for character formation is between 0.7 and 0.8,[1] resulting in dot matrix character sizes of 5 by 7 and 7 by 9. The stability of the image on the display screen is usually good as long as a stable power supply is provided and the voltage levels are compatible with the operating levels of the VDT. As soon as a character is projected onto the display screen, it begins to fade at a rate which depends on the persistence of the screen phosphor. To keep the character visible on the screen, the signal must be regenerated or 'refreshed' continually. VDTs operating with a refresh rate of 60Hz, and using medium duration phosphors, do not produce discomfort due to the perceived periodic dimming and brightening of the display. This is true provided the phosphors are not beyond their recommended screen life. The brightness of the letters on the screen must exceed the minimum acceptable level for legibility yet not be so

bright as to distract or cause glare. Contrast between the symbols and the luminance of the background is important. Both brightness and contrast influence the visual acuity of an individual operator. A brightness control knob allows each operator some adjustment for character luminance.

Keyboard

It is considered that the characteristics of the keyboard play a major role as far as the incidence of fatigue and other forms of discomfort among VDT operators is concerned. Among the factors to consider are keyboard profile and angle, keyboard thickness and feedback to the operator. The profile angle of the keyboard should be between 5° and 15° to minimize fatigue in the hands and to ensure good keying performance. The most favourable arm position would be the keyboard rested directly on the thighs. In practice, however, it is desirable to keep the thickness of the keyboard (the distance from the base of the keyboard to the home row of keys) to a minimum (about 30 mm). Also, a palm rest helps reduce fatigue in the wrist and arm.[10] Some tactile feedback or audible click to indicate that the keystroke has been actioned aids both skilled and unskilled operators in the self-detection of omitted and/or duplicated keystrokes.

Work Environment

Glare

Glare is caused when bright sources of light (for example, from light fixtures, windows or their reflected images) fall within the operator's field of vision. Visual discomfort may result since the processes of visual adaptation are disturbed. Also, neck and back pains may occur if the operator adopts a poor body posture to minimize the glare.

Care should be taken to ensure that the VDT is not viewed against a bright background such as a window or a white wall.[7] In such a case, the pupils adjust to the total light entering the eyes, and the images on the screen will become more difficult to see. Direct glare from light fixtures may have the same effect. Reflected glare from large glossy surfaces such as walls and desk tops can also be a

cause of visual discomfort. Walls can be textured in neutral tones to reduce reflected light. Working surfaces should have a non-glare finish. Reflections on the face of the VDT screen produce an additional visual image which can make it difficult to see the characters on the screen. Light fixtures should be shielded so as to avoid reflection on the display screen while windows should be shielded by pattern-free curtains or roll blinds. Venetian blinds can cause a pattern of light stripes, especially on sunny days. Screen filters can reduce reflections on the screen and thereby improve the visual quality of the display.

Ambient Lighting

The illumination required for VDT operation is determined by the complexity and visual difficulty of the task. Since the appearance of many working interiors is gloomy at illuminances less than about 200 Lux, this minimum illumination is generally recommended for normal working spaces irrespective of the visual ease of the task.[11] Lighting must be sufficient to ensure that the source documents can also be read clearly and easily; if text to background contrast is less than 0.5, reading is impeded.[13] Since control of glare is also a consideration, it has been recommended by Cakir *et al*[1] that VDT work areas should be illuminated with 300 to 500 Lux illuminance and with the best possible glare shielding to safeguard against both direct and reflected glare. Suitable task lighting for the source document may be required.

Workplace Design

The likelihood that the operator of a VDT may experience feelings of fatigue or stress at work is governed to a very large extent by his or her sitting position while operating the VDT. The design of the workplace must take account of the position and freedom of movement required by the hands, arms, legs and head, as well as the viewing distances involved while working with the VDT screen, keyboard and source documents. A machine stand that permits independent adjustment of both the keyboard and screen height allows adjustment for operator preferences and for operators of different body size.

The ideal arrangement is a VDT with a keyboard detached from the display screen and an adjustable machine stand. This allows the operator to adjust the setting of the screen and keyboard to a position which minimizes neck and shoulder strain. The chair height should be adjusted to enable 'keyboarding' in a position with the forearms approximately horizontal. The feet should rest comfortably on the floor with the thighs horizontal. If the user is unable to adopt such a position without stretching, then a foot rest should be provided. The provision of a back rest helps to minimize the static muscular work while sitting. The position of the back rest should be adjustable both in height and in angle. Bending the head forward at an angle of no more than 20° from the vertical is the most comfortable position for viewing the screen and source documents. A document holder should be provided since less strain is put on the neck when the head is rotated from side to side rather than up and down. Generally, the document holder is placed next to, and in the same horizontal and vertical plane as, the display screen. In addition to the space provided for the screen, keyboard and document holder, most job tasks require space for reference books, source documents and storage of paper. Printers, if located near the operator, should be placed on a separate table to reduce vibration and be provided with a noise cover.

Work Task

Rest Pauses

The work task should, as far as possible, be designed so that rest pauses allow the operator to remain physically and mentally efficient. The recovery value of rest pauses is not solely dependent upon the length of the pause but also upon when it is taken. There is evidence that frequent pauses which are taken before the onset of high levels of fatigue are much more effective than longer but less frequent rest pauses which are taken after longer periods of continuous work.[14] Indeed, it appears that the most favourable regulation of rest pauses occurs when pauses are taken prior to the onset of a no-

ticeable degree of fatigue. Pause times of between five per cent and 10 per cent of the total work time are compensated by the recuperating effects of the pauses.

Rest pauses should not be confused with inactivity or waiting time during VDT use since the operator cannot become disengaged from the work task. Interruptions of unpredictable duration at critical stages of the task while waiting for a machine generated response, may add, rather than reduce, stress. Such a period of apparent inactivity may have no recovery value and may even add to the operator's level of fatigue.

Task Demands

Both job demands and task control are important factors in determining the level of job stress reported by VDT operators.[8-9] Typically, those who report high work pressure and workload, fast work pace and boring and repetitive work tasks as their major sources of stress, hold jobs that involve rigid work procedures with high production standards, constant pressure for performance, very little operator control over job tasks and little identification with, and job satisfaction from, the final product of the work activity.[8] In contrast, the majority of VDT operators who hold jobs that allow for flexibility in work strategies, individual control over how job demands are met, autonomy and a great deal of job satisfaction and pride in the final product, have fewer concerns about task demands in spite of high production standards and tight deadlines. The greatest sources of stress for these operators are concern over career development and future job activities.

These needs are not unique to VDT operators. Indeed, such needs are consistent with the psychological requirements known to arise from the job itself and from the work organization in which the jobs are embedded.[15] Thus job enrichment, job rotation and the formation of work-sharing groups are all effective ways to increase the creative aspects of jobs. However, the involvement of users at each stage in the planning and selection of a VDT system is also an essential feature of successful VDT implementation.

Conclusion

Possible adverse health effects may result from working with VDTs. Avoiding such problems depends on the equipment, work environment and work task being designed to promote the comfort and efficiency of the operators. Employees, employers, unions and occupational health and safety personnel should consider these areas before, not after, the VDT is introduced into the workplace.

References

[1]Cakir AD, Hart J, Stewart TFM. Visual Display Terminals. John Wiley and Sons Ltd, 1980.

[2]Coates S. The Office of the Future. Department of Communications, Government of Canada, 1981.

[3]Muc AM. Video Display Terminals — A Radiation Hazard? Proceedings of the 14th annual meeting, Human Factors Association of Canada 1981; 45-47.

[4]Gorrell EL. Visual Fatigue, Legibility and Electronic Displays. Proceedings of the 14th annual meeting, Human Factors Association of Canada, 1981; 48-54.

[5]Dainoff MF. Visual Fatigue in VDT Operators. In: Grandjean E and Vigliani E. eds, Ergonomic Aspects of Visual Display Terminals. London: Taylor and Francis Ltd, 1980; 95-99.

[6]Laubli T, Hunting W, Grandjean E. Visual Impairments in VDU Operators Related to Environmental Conditions. In: Grandjean E and Vigliani E. eds, Ergonomic Aspects of Visual Display Terminals. London: Taylor and Francis Ltd, 1980; 85-94.

[7]Ostberg O. Health Problems for Operators Working with CRT Displays. In Occup Health and Safety November/December, 1975; 24-52.

[8]Smith MJ, Stammerjohn LW, Cohen BGF, Lalich NR. Job Stress in Video Display Operations. In: Grandjean E and Vigliani E. eds, Ergonomic Aspects of Visual Display Terminals. London: Taylor and Francis Ltd, 1980; 201-210.

[9]Elias RF, Cail F, Tisserand M, Christmann H. Investigations in Operators Working with CRT Display Terminals: relationship between task content and psychophysiological alterations. In: Grandjean E and Vigliani E. eds, Ergonomic Aspects of Visual Display Terminals. London: Taylor and Francis Ltd, 1980; 211-217.

[10]Hunting W, Laubli TL, Grandjean E. Constrained Postures of VDU Operators. In: Grandjean E and Vigliani E. eds, Ergonomic Aspects of Visual Display Terminals. London: Taylor and Francis Ltd, 1980; 175-184.

[11]Kaufman JE, Christensen JF. eds, IES Lighting Handbook. 5th edition. New York: Illuminating Engineering Society, 1972.

[12]Zerbe LB, Hofstetter HW. Prevalence of 20/20 with Best Previous and No Lens Correction. J Amer Optom Assoc 1957; 29: 772.

[13]Timmers H, Van Nes FL, Blommaert FJJ. Visual Word Recognition as a Function of Contrast. In: Grandjean E and Vigliani E. eds, Ergonomic Aspects of Visual Display Terminals. London: Taylor and Francis Ltd, 1980; 115-120.

[14]Grandjean E. Fitting the Task to the Man: An Ergonomic Approach. London: Taylor and Francis Ltd, 1980.

[15]Trist E. The Evaluation of Socio-Technical Systems. Issues in the Quality of Working Life. Ontario Quality of Working Life Centre, Ontario Ministry of Labour, 1981; No 2, June.

Book Review

New Perspectives on Noise Induced Hearing Loss.

Edited by R. P. Hamernik, D. Henderson and R. Salvi

New York: Raven Press, 1980. 534 pp. Price: $30.00

This book is a recent publication of proceedings from a conference sponsored by NIOSH and held at Cazenovia, New York, in June 1980. It is a sequel to the 1976 publication *Effects of Noise on Hearing* and it reviews the current status of research related to noise induced hearing loss.

The book presents a wide range of basic and applied experimental studies, which are organized under the following topics: Anatomy and Biochemistry of Noise Induced Hearing Loss, Physiology of Noise Induced Hearing Loss, Experimental Studies of Permanent Threshold Shift and Temporary Threshold Shift, Auditory Performance Changes with Noise Induced Permanent Threshold Shift, and Noise Standards, Economics and Demographic Considerations.

The first three topics include studies which document the anatomical, physiological and behavioural changes in the auditory system following noise exposure. One interesting finding among this group of studies is the reported site of lesion. It would appear that the effects of noise exposure can not only be demonstrated in the inner and outer hair cells of the cochlea, but also at the level of the brain stem and the brain.

The last two topics include studies which evaluate the relationship between noise exposure and damage to hearing. Both the equal energy hypothesis and equal temporary effects hypothesis are addressed. It would appear that the equal energy hypothesis, i.e. the 3dB exchange rate, is still the only valid approach to establishing a relationship between noise exposure and permanent noise induced hearing loss.

In this section, too, there are studies which have relevant information related to field application, i.e. a review of instruments and procedures for noise measurement and practical aspects in the use of hearing protection.

This book is not an introductory text; it is designed primarily for researchers. It would, however, be extremely valuable to anyone requiring an up-to-date text on noise induced hearing loss. *M. J. Pike*

Publications Available from the Government Book Store

Publications under the Regulation Act vol. 112-39	
O. Reg. 658/79 as amended by O. Reg. 844/79 Industrial Establishments	$1.50
O. Regs. 659/79 as amended by O. Reg. 845/79 Construction Projects	$1.50
O. Regs. 660/79 as amended by O. Reg. 846/79 Mines and Mining Plants	$1.50
The Nursing Consultant	$2.00
A Guide to The Occupational Health and Safety Act, 1978	$1.00
Regulation respecting Lead — made under the Occupational Health and Safety Act Revised Statutes of Ontario, 1980 Chapter 321	$1.00
Regulation respecting Mercury — made under the Occupational Health and Safety Act Revised Statutes of Ontario, 1980 Chapter 321	$1.00

News and Notes

Retirement of Dr. Maxwell Fitch

Dr. Maxwell Fitch, who retired from the Ontario Public Service on May 31, 1982, has had a long and distinguished career in preventive medicine.

He was born in Quebec City and attended McGill University, where he received the degrees of B.Sc. and M.D. Later, he obtained his D.P.H. at the University of Toronto and his D.I.H. in London, England.

During the war he was an army medical officer in Labrador and England. From 1946 to 1949 he was hospital commander and senior medical officer for the North West Highway System. While stationed in Whitehorse, NWT he met his wife, who was a nursing sister at that time.

From 1966 to 1969 he was director of preventive medicine for the Canadian Armed Forces.

Since he joined the Ontario Government, he held, while in the Ministry of Health, the positions of medical consultant to the Ministry of the Environment and acting director of the Occupational Health Protection Branch. During this time, he was seconded by the federal government for 2½ years to work with the Canadian International Development Agency to set up a Department of Public Health in the medical faculty of the University of Cameroon, West Africa.

For the past four years he has been director of the Special Studies and Services Branch of the Ministry of Labour, which is concerned with health and safety studies and the evaluation of radiation hazards.

Canadian Acoustical Association Seminars Toronto, October 18-19, 1982

The 1982 meeting of the Canadian Acoustical Association will be held at the Westbury Hotel, Toronto during the week of October 18, 1982.

Two concurrent two-day seminars will be offered on October 18 and 19, which will be of particular interest to the acoustical and industrial communities:

1) **Noise In The Workplace**
The proposed Ontario Noise Regulation will be examined in a multi-session program. Physics of sound, effects of noise on humans, noise measurement, hearing conservation, engineering controls, hearing protection, medical surveillance, standards and the regulation will be covered.

2) **Vibration**
Aspects of vibration will be examined in a multi-session program. Random excitation, analysis, case studies, experimental methods, instrumentation, control of vibration, effects on humans, standards and regulations will be covered.

Seminar Fee: $100.00 per person

Requests for information and seminar registrations should be forwarded to:

John Manuel
5007 - 44 Charles West
Toronto, Ontario
M4Y 1R8

Post-Graduate Program in Occupational Health

The Occupational and Environmental Health Unit, Faculty of Medicine, University of Toronto offers post-graduate degree programs to physicians, nurses and scientists undertaking further training in the field of occupational health.

1) Diploma in Industrial Health (D.I.H.): nine months full-time professional training or five years part-time in the field of industrial and occupational health and safety.

2) Master of Health Science (M.H.Sc.): specialization — Occupational and Environmental Health. A community health based, 16-24 months full-time professional training, but following one year full-time attendance the balance of the degree work may be completed on a part-time basis up to five years from first date of registration. A core course each term introduces basic theoretical and methodological approaches used in community health, and specialist courses examine all

the effects of the work health relation. A thesis is not required, but major papers are undertaken. A four-month summer practicum is required. The two-year program is approved by the Royal College of Physicians and Surgeons as part of a four-year training for the Fellowship in Community Medicine with Occupational Medicine as the field of concentration. The Canadian Board of Occupational Medicine gives official recognition to the training.

3) Master of Science (M.Sc.): a two-year program based on research and the writing of a thesis is available in the areas of occupational health and hygiene.

Occupational and Environmental Health Unit, Faculty of Medicine, University of Toronto, FitzGerald Building, 150 College Street, Toronto, Ontario. M5S 1A1. Tel. (416) 978-4353.
Director: J.R. Nethercott, M.D., F.R.C.P.(C)
Program Director: G.J. Stopps, M.B., B.S.
Contact Person: Valerie M.D. Alcock, M.B., B.S. Tel: (416) 978-4521

Coming Events

August 23-25, 1982	Second International Symposium on Epidemiology in Occupational Health, Montreal, Quebec
August 28- September 2, 1982	American Chemical Society Symposium on Chlorinated Diseases and Dibenzofurans in the Total Environment, II
September 5-10, 1982	10th Asian Conference on Occupational Health, Singapore
September 12-17, 1982	American Chemical Society Symposium on Chlorinated Dioxins and Dibenzofurans in the Total Environment, I, Kansas City, Missouri
September 21-24, 1982	ILO Symposium on the Protection of Workers against Vibration, Niš (Yugoslavia)
October 4-8, 1982	Five-day International Conference on Fibrous Dusts, Strasbourg, France
October 14, 1982	World Congress on Diseases of the Chest, Toronto, Ontario
October 25-29, 1982	Ontario Occupational Health Nurses' Association Conference, Niagara Falls, Ontario
October 29-30, 1982	Society of Occupational Medicine Autumn Meeting, London, England
March 24-25, 1983	Society of Occupational Medicine Spring Meeting, London, England
May 8-13, 1983	10th World Congress on the Prevention of Occupational Accidents and Diseases, Ottawa, Ontario

Ontario
Ministry of
Labour

Occupational
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Occupational
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